Nuclear structure effect in the 223 keV M1 transition in ^{133}Cs

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Introduction

The penetration of the electronic wave function inside the nucleus makes the internal conversion coefficient (ICC) sometimes sensitive to the details of nuclear structure. According to the theory of Church and Wenesar [1] penetration effects are expected to be particularly large for *l*-forbidden M1 transitions with Δ*l*=2. The penetration parameter λ in M1 transitions is the ratio of the penetration matrix element to the gamma-ray matrix element. So it can be expected that the most retarded M1 transitions would probably show the strongest internal conversion penetration effects. Penetration effects give information on nuclear structure and their existence shows up as large errors in the conversion coefficients or as discord between the results obtained through various methods. The deviation of ICCs from the theoretical values for the highly retarded γ-transitions occurs as a result of the penetration effect in internal conversion.

The 223 keV transition in ^{133}Cs is one of the several cases for which anomalous conversion coefficients have been reported [2-7]. The retardation factor of this transition is ~2000 Weisskopf units. As can be seen from Table I, there is a large disagreement among the values of $\alpha_K(223)$ which appear in the literature. Clearly, a more fundamental understanding of the anomalous internal conversion process will depend on the comparison of the experimental values of α_K and λ for such a case. The previously reported values of $\alpha_K(223)$ are neither accurate nor consistent enough to be useful in a determination of λ(223). We have investigated the penetration effects in this transition by re-measuring the $\alpha_K(223)$. Also the accuracies of the theoretical ICCs are now very much improved with the availability of BRICC [8] data as compared to Hager and Seltzer [9] data which would improve the accuracy with which λ(223) is determined.

Experiment

^{133}Ba was obtained from Bhabha Atomic Research Centre, Trombay as $BaC1_2$ in HCl solution. Volatilized sources on 180 μg/cm^2 mylar were prepared. Insulin was used to define the source area and help in spreading of the source. A 60 cc HPGe detector coupled to a PC based 8K MCA gamma spectrometer optimized for its best performance parameters has been used for recording the gamma spectra. A LN_2 cooled windowless EG&G ORTEC BETA-X Si(Li) detector optimized for the required energy range was used for recording the conversion electron spectra. The details of the electron and gamma spectroscopic systems have been discussed elsewhere. These systems have been proved and used for precision spectroscopic measurements. FIT and Gamma Vision software have been used for spectral analysis.

Results and Discussion

The intensity of the K-conversion line of the 223 keV transition relative to the K- conversion line of the intense 356 keV transition was obtained to be 0.0068(20). The γ-ray intensity relative to the 356 keV transition was obtained from the HPGe data. The K-conversion coefficient of the 223 keV transition is given by

$$\alpha_K(223) = \frac{N_{e(K)}(223)\ N_\gamma(356)}{N_{e(K)}(356)\ N_\gamma(223)}\ \alpha_K(356)$$

Here, $N_{e(K)}(223)$ is the internal conversion electron intensity relative to the conversion line intensity $N_{e(K)}(356)$ of the 356 keV transition. $N_\gamma(223)$ is the gamma intensity of the 223 keV transition relative to the gamma intensity $N_\gamma(356)$ of the 356 keV transition.

$\alpha_K(356)$ is the theoretical conversion coefficient of the 356 keV transition which is of pure E2 character. The $\alpha_K(356)$ E2 was interpolated from the tables of BRICC as 0.021. The K-conversion coefficient obtained by the above equation is given in the Table 1 along with the previously reported results.

Table 1: K-conversion coefficients of the 223 keV transition.

Measurement	$\boldsymbol{\alpha_K(223)}$
A. Notea and Gurfinkel [4]	0.076 ± 0.0086
Yu. V. Sergenkov	0.081 ± 0.006
H. E. Bosh et al [3]	0.06 ± 0.02
K. V. Ramaniah et al [7]	0.092 ± 0.01
F. T. Avignone et al [6]	0.082 ± 0.004
Present work	0.068 ±0.02
BRICC M1	0.084
BRICC E2	0.091

The M1 internal conversion coefficient for any sub-shell depends on the penetration parameter λ through the relation

$$\alpha(\lambda,\delta) = \frac{\beta(M1)(1+B_1\lambda+B_2\lambda^2) + \delta^2\alpha(E2)}{1+\delta^2}$$

where $\beta(M1)$ and $\alpha(E2)$ are the theoretical ICCs interpolated from BRICC [9] data and B_1 and B_2 are the penetration functions tabulated by Hager and Seltzer [10]. The results of the γ-γ angular-correlation measurements for $\delta(223)$ have been employed along with our $\alpha_K(223)$= 0.068(20) for the determination of the λ from the above equation. From a graph between λ and α_K, the λ corresponding to experimental $\alpha_K(223)$ is found to be 13±4. Table 2 shows our results of the penetration parameter λ along with those reported by different authors. The average of the values of λ(223) for the present $\alpha_K(223)$ and the various $\delta(223)$values is found to be 13±4. The average of the higher possible range of λ implied by the data is 228 ± 68.

Table 2: Penetration parameter λ

Measurement	**Penetration parameter λ**
Tornkvist et al [2]	15 ± 4
Avignone et al [6]	2 ± 4
Ramaniah et al [7]	10 ± 0.5
Present work	13 ± 4

It is interesting to consider the poor correlation between the retardation of the gamma ray matrix element and the penetration parameter for the three highly retarded, predominantly M1 transitions in ^{133}Cs as seen from the Table 3.

Table 3:

$\boldsymbol{\delta}$	$\boldsymbol{\delta^2}$	$\boldsymbol{\lambda_1}$	$\boldsymbol{\lambda_2}$
-0.108	0.0117	12.47	228.76
0.08	0.0064	12.37	228.86
0.27	0.0732	13.67	227.57
0.4	0.1610	15.39	225.84
0.114	0.0129	12.49	228.74

Table 4: Retardation and penetration parameter for various transitions in ^{133}Cs.

Transition	**Retardation**	**λ**
81 keV	420	3±2
161 keV	230	34±7
223 keV	2000	13±4

The lack of one-to-one correspondence about the large retardation and large λ, especially in the case of 223 keV transition, as can be seen from the Table 4, clearly indicates that some selection rules other than those which would retard the M1 γ- ray transition plays a dominant role in the internal conversion process of the 223 keV transition. The existing discrepancies in the mixing ratios can be resolved by assuming that dynamic-structure effects exist in the internal-conversion process of the 223 keV transition and that the value of the nuclear-structure parameter λ.

References

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